LONGWAVE AND WINDOW ANGULAR DISTRIBUTION MODELS FROM CERES/TRMM RADIANCE MEASUREMENTS

Natividad Manalo-Smith
Analytical Services and Materials, Inc., Hampton, VA

Norman G. Loeb
Center for Atmospheric Research, Hampton University, Hampton, VA

Konstantin Loukachine
SAIC, Hampton, VA

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INTRODUCTION

In monitoring and understanding the Earth's radiation budget, accurate retrievals of top-of-atmosphere (TOA) radiative fluxes are needed. To estimate TOA fluxes from satellite radiance measurements, angular distribution models (ADMs) that account for the anisotropy of Earth scenes are required. The Clouds and Earth's Radiant Energy System (CERES) instrument together with the Visible Infrared Scanner (VIRS) on board the Tropical Rainfall Measuring Mission (TRMM) satellite provide a unique dataset for developing ADMs. The CERES instrument is capable of acquiring multiangle measurements in a rotating azimuth plane scan mode (RAPS)—where the instrument scans in elevation as it rotates in azimuth—and also of scanning in elevation in a fixed scan mode (e.g. alongtrack and crosstrack directions). Each CERES footprint is observed by high-resolution VIRS measurements which identify scene type parameters that influence its anisotropy.

OBJECTIVES

- **To describe the development of empirical longwave and window ADMs from CERES-TRMM dataset.**

- **To present a preliminary set of ADMs.**

- **To present early validation results of fluxes generated from this set of ADMs.**

METHOD

- Composite radiance measurements into view zenith angle ranges and scene types consisting of a combination of the underlying surface types (e.g. ocean, land, desert), cloud cover (clear, overcast, and broken cloud fields), and fixed percentile intervals of atmospheric and cloud properties (e.g. cloud emissivity, precipitable water, lapse rate).

- Compute an average radiance measurement for each combination of scene type parameters and view zenith angle. To fill in empty angular bins, observed radiances in existing angular bins are extrapolated using theoretical model calculations.

- Calculate radiant flux *M* using the Gauss quadrature integration from mean radiance measurements *L* over the range of viewing zenith angle θ:

$$M = 2\pi \int_0^{\frac{\pi}{2}} \sin\theta \cos\theta \, L(\theta) \, d\theta$$

- Compute angular distribution model *R* from

$$R(\theta) = \frac{\pi L(\theta)}{M}$$

DATA

- **Source:** CERES-TRMM [as recorded on hourly-based Single Scanner Footprint TOA/Surface Fluxes and Clouds (SSF) data product]
- **Time Period:** January through August 1998
- **Scan Mode:** RAPS and Alongtrack Data
- **Latitude Coverage:** +/- 35 degrees

ADM Category		Scene Type Stratification	Total
CLEAR	Ocean	3 Precipitable Water	15
		5 Vertical Temp. Change (T_{sfc}-$T_{sfc-300mb}$)	
	Land	3 Precipitable Water	15
		5 Vertical Temperature Change	
	Desert	3 Precipitable Water	15
		5 Vertical Temperature Change	
BROKEN CLOUD FIELD (4 cloud intervals)	Ocean/Land	3 Precipitable Water	288(O) 288(L)
		6 T(surface-cloud)	
		4 IR Emissivity	
OVERCAST	Ocean + Land	3 Precipitable Water	126
		7 T(surface-cloud)	
		6 IR Emissivity	

Table 1: PRELIMINARY SCENE TYPES FOR CERES-TRMM LONGWAVE/WINDOW ADMs

Precipitable Water Percentile Interval (%)	**Vertical Temperature Change Interval (%)**
	VTC < 0 (deg)
0 - 33	0- 25
33 - 66	25- 50
66 - 100	50 - 75
	75 -100

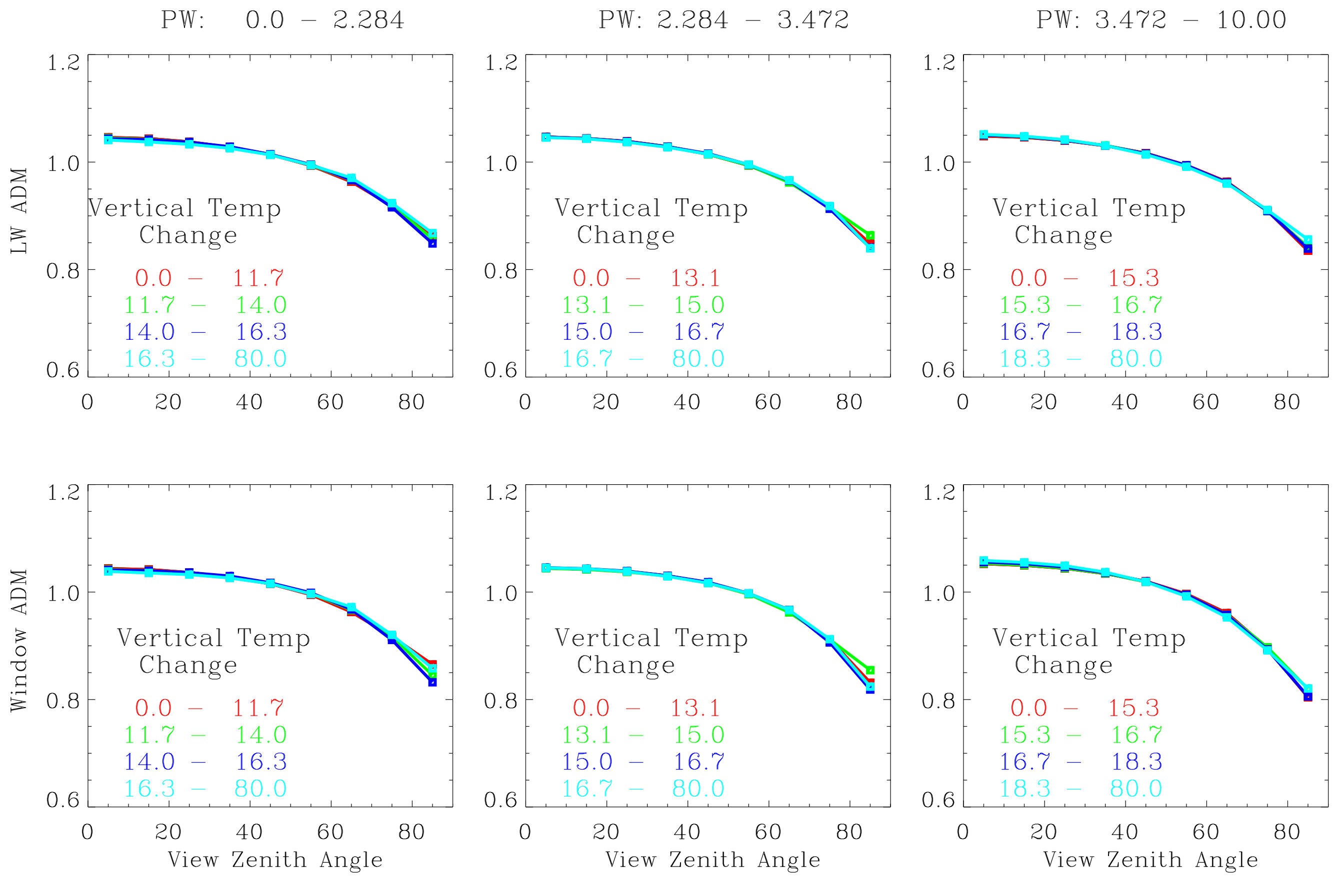
Table 2: ADM SCENE TYPE PARAMETER PERCENTILE INTERVALS FOR CLEAR SKY SCENES

<table>
<tr><th rowspan="2">Precipitable Water Percentile Interval</th><th colspan="3">Broken Cloud Fields</th><th colspan="2">Overcast</th></tr>
<tr><th>Cloud Fraction Interval</th><th>T(Sfc-Cloud Effective) Percentile Interval</th><th>IR Emissivity Percentile Interval</th><th>T(Sfc-Cld Effective) Percentile Interval</th><th>IR Emissivity Percentile Interval</th></tr>
<tr><td rowspan="7">0 - 33
33 - 66
66 - 100</td><td rowspan="7">0.1 - 25
25 - 50
50 - 75
75 - 99</td><td>$\Delta T < 0$ deg</td><td>0 - 25</td><td>$\Delta T < 0$ deg</td><td>0 -5</td></tr>
<tr><td>0 -20</td><td rowspan="2">25 - 50</td><td>0 -20</td><td>5 - 10</td></tr>
<tr><td>20 - 40</td><td>20 - 40</td><td>10 -25</td></tr>
<tr><td>40 - 60</td><td rowspan="2">50 - 75</td><td>40 - 60</td><td>25 - 50</td></tr>
<tr><td>60 -80</td><td>60 -80</td><td>50 -75</td></tr>
<tr><td rowspan="2">80 - 100</td><td rowspan="2">75 - 100</td><td>80 - 90</td><td rowspan="2">75 - 100</td></tr>
<tr><td>90 - 100</td></tr>
</table>

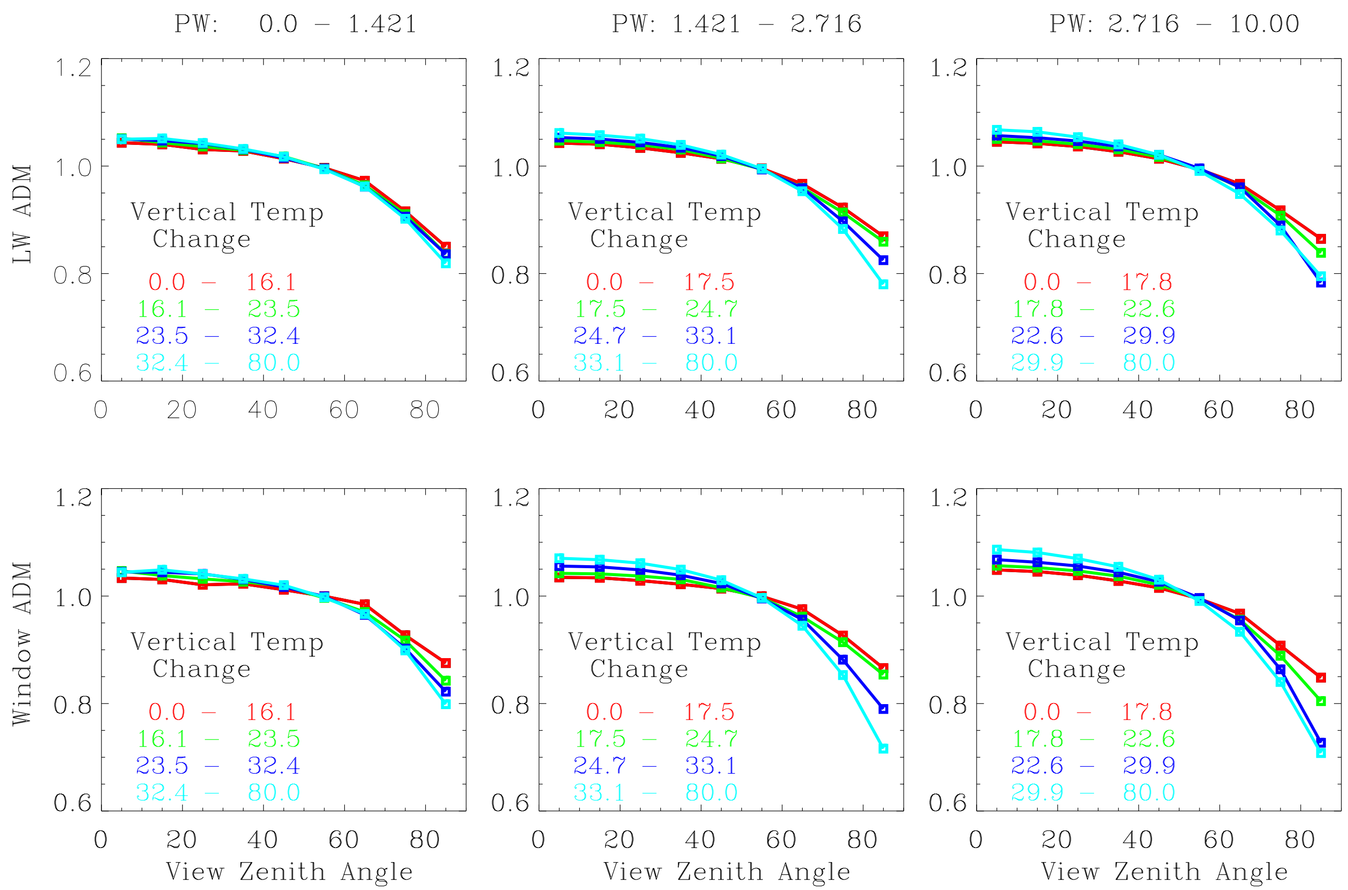
Table 3: ADM SCENE TYPE PARAMETER PERCENTILE INTERVALS FOR BROKEN CLOUD FIELDS AND OVERCAST SCENES

RESULTS

VARIATION OF CLEAR SKY (OCEAN) LW/WINDOW ADM
WITH PRECIPITABLE WATER AND VERTICAL TEMPERATURE CHANGE

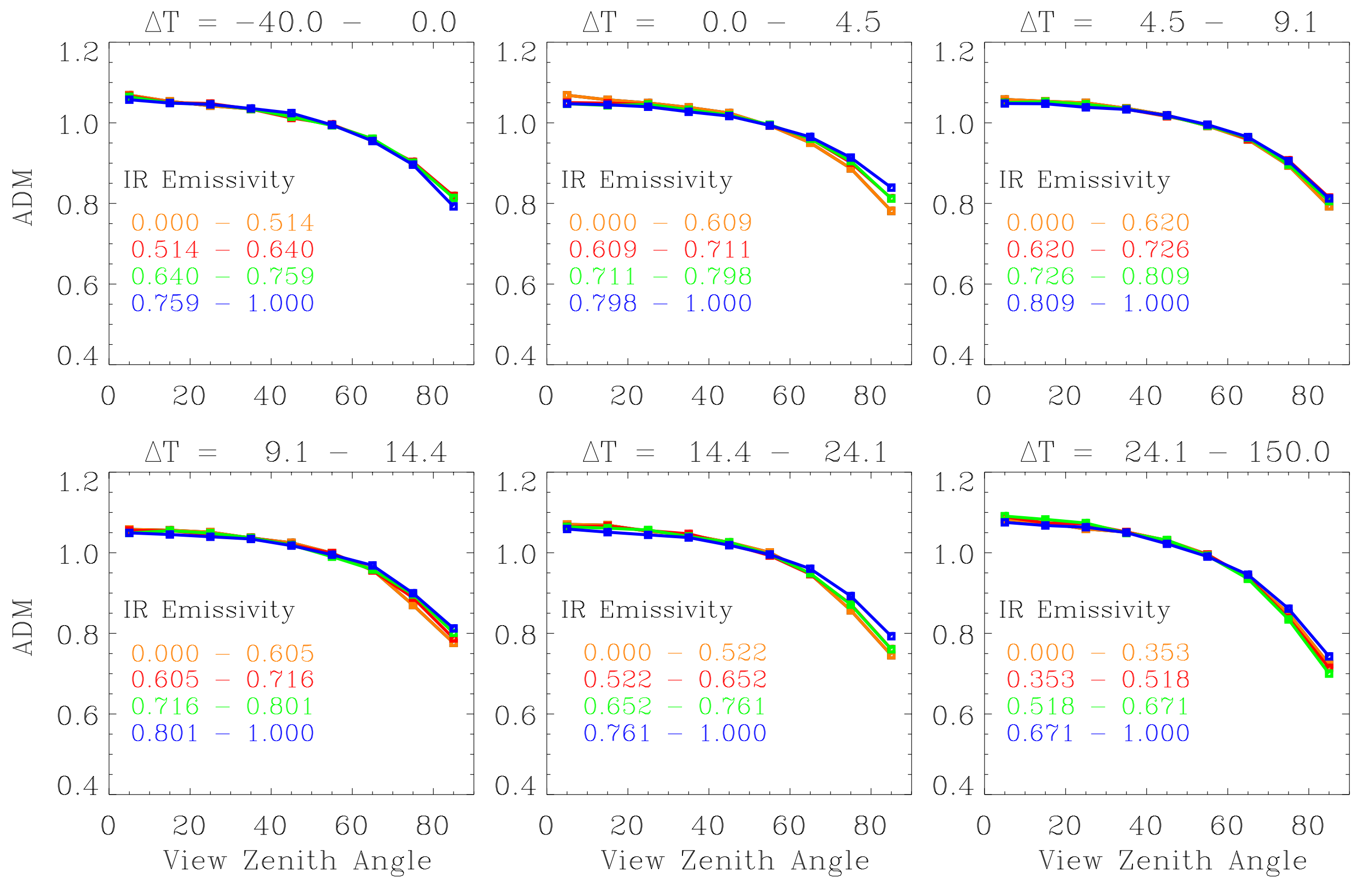


VARIATION OF CLEAR SKY (LAND) LW/WINDOW ADM
WITH PRECIPITABLE WATER AND VERTICAL TEMPERATURE CHANGE



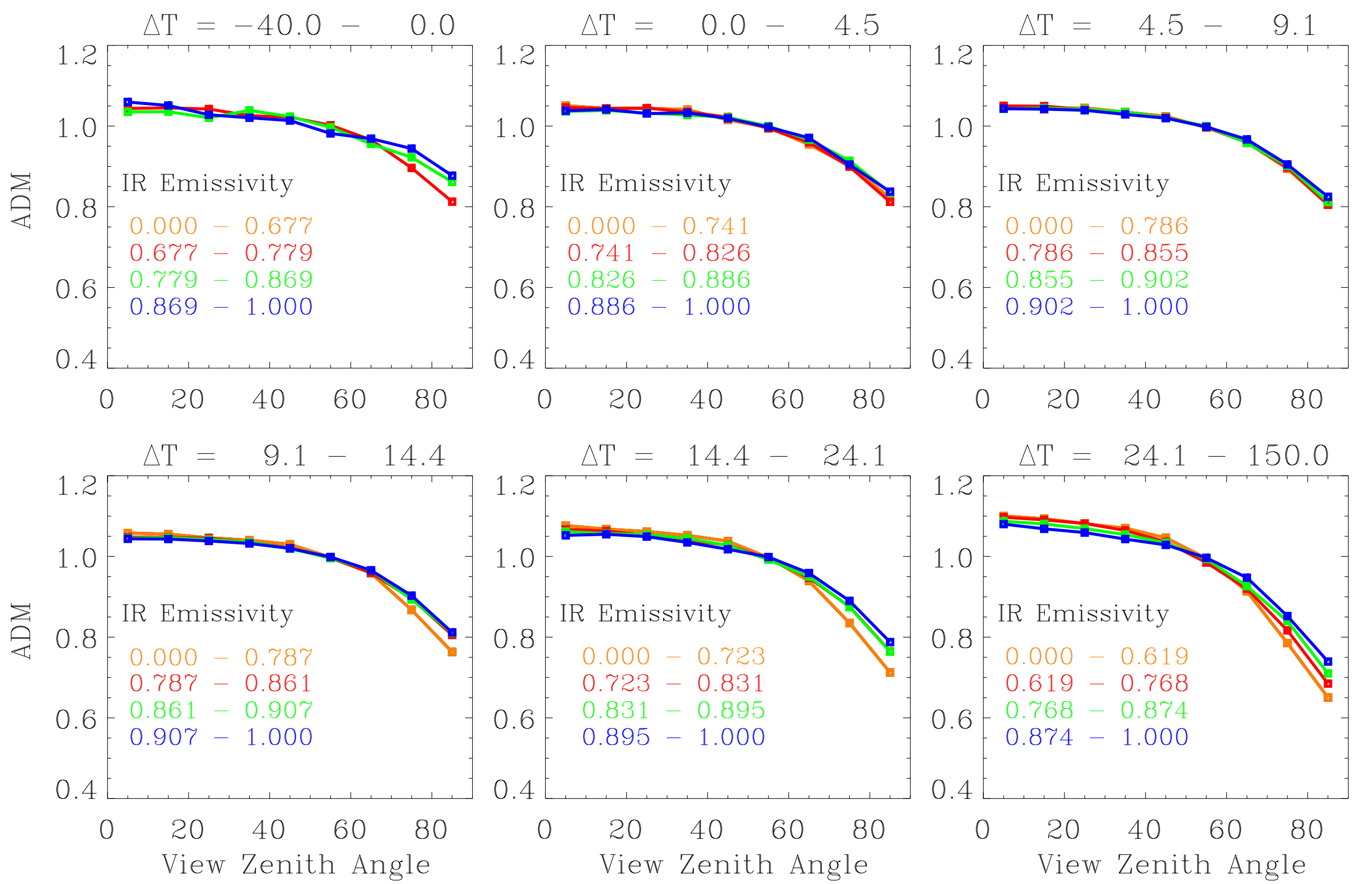
VARIATION OF LW ADM FOR BROKEN CLOUD FIELDS (LAND) WITH PRECIPITABLE WATER, ΔT(SFC-CLD EFFECTIVE TEMP) AND IR EMISSIVITY

Precipitable Water: 0.00-2.69 Cloud Fraction: 25 - 50



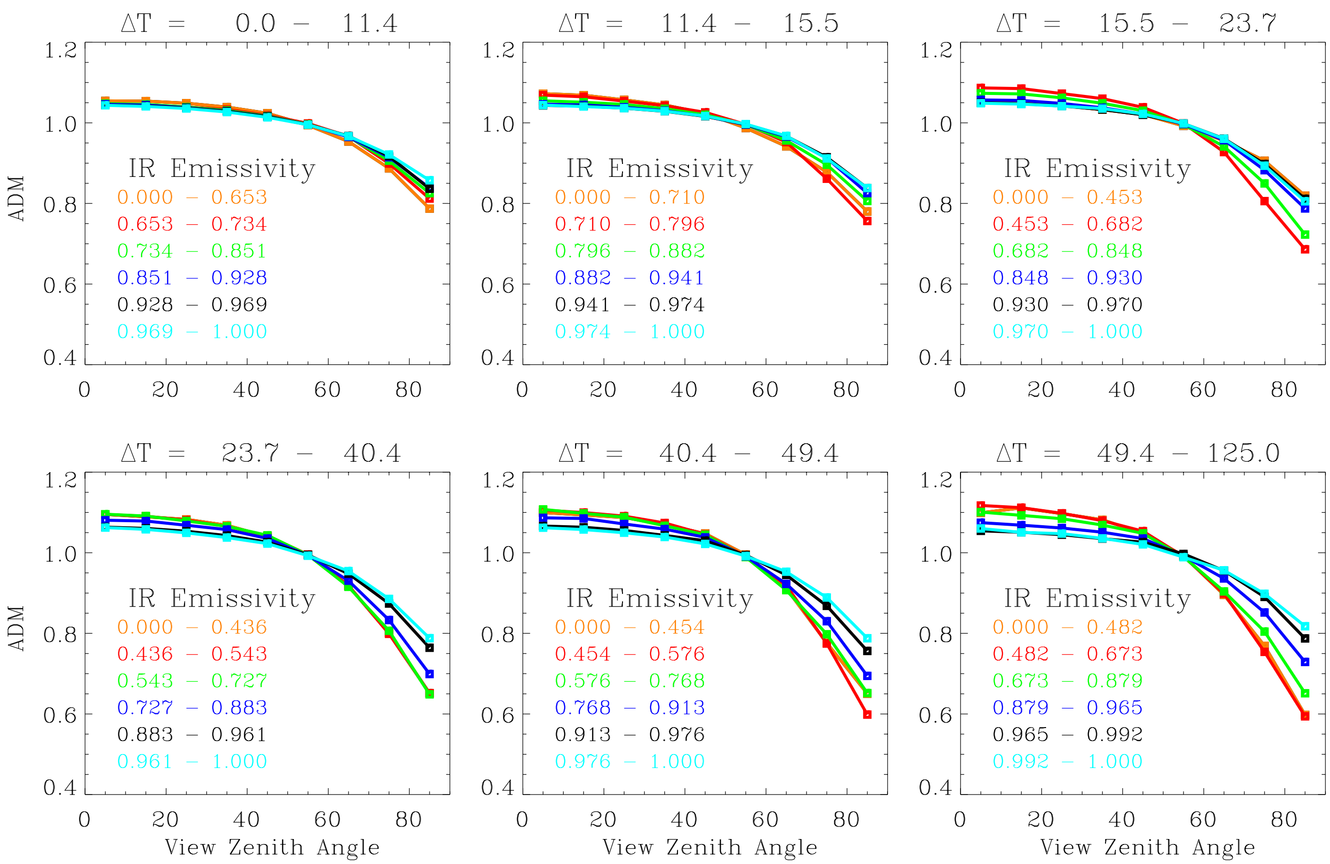
VARIATION OF LW ADM FOR BROKEN CLOUD FIELDS (LAND) WITH PRECIPITABLE WATER, ΔT(SFC-CLD EFFECTIVE TEMP) AND IR EMISSIVITY

Precipitable Water: 0.00-2.69 Cloud Fraction: 75- 99



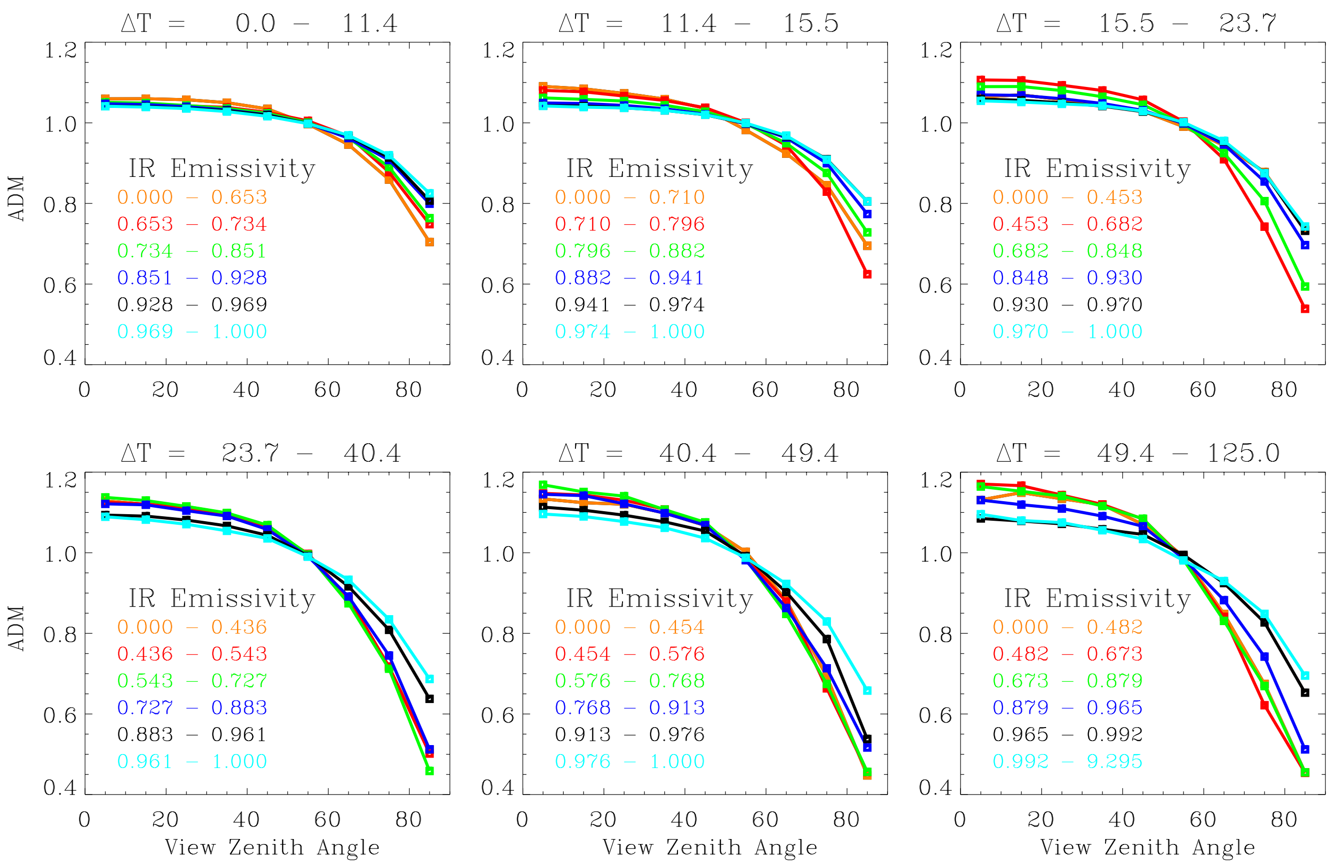
VARIATION OF OVERCAST LW ADM (OCEAN & LAND) WITH
PRECIPITABLE WATER, ΔT(SFC-CLD EFFECTIVE TEMP) AND IR EMISSIVITY

Precipitable Water: 0.00-2.52



VARIATION OF OVERCAST WN ADM (OCEAN & LAND) WITH PRECIPITABLE WATER, ΔT(SFC-CLD EFFECTIVE TEMP) AND IR EMISSIVITY

Precipitable Water: 0.00-2.52



- CLEAR SCENES
  - Anisotropy increases with precipitable water for all surface types.
  - Clear ocean ADMs exhibit little dependence on vertical temperature change.
  - Anisotropy over clear land and desert increases with vertical temperature change.

- BROKEN CLOUD FIELDS SCENES
  - ADMs show more dependence on cloud emissivity than on PW or $\Delta T_{(\text{Sfc-Cld Effective T})}$.
  - As cloud cover increases, anisotropy increases. The increase is more pronounced for larger cloud fractions
  - Land scenes are more anisotropic than ocean scenes

- OVERCAST SCENES
  - ADMs show the largest dependence on cloud emissivity.
  - Anisotropy increases as cloud emissivity decreases.
  - As PW and $\Delta T_{(\text{Sfc-Cld Effective T})}$ increases, anisotropy increases.

- WINDOW CHANNEL ADMs
  - WN ADMs show a similar dependence on scene type parameters as the LW ADMs, but are generally more anisotropic than the LW ADMs.

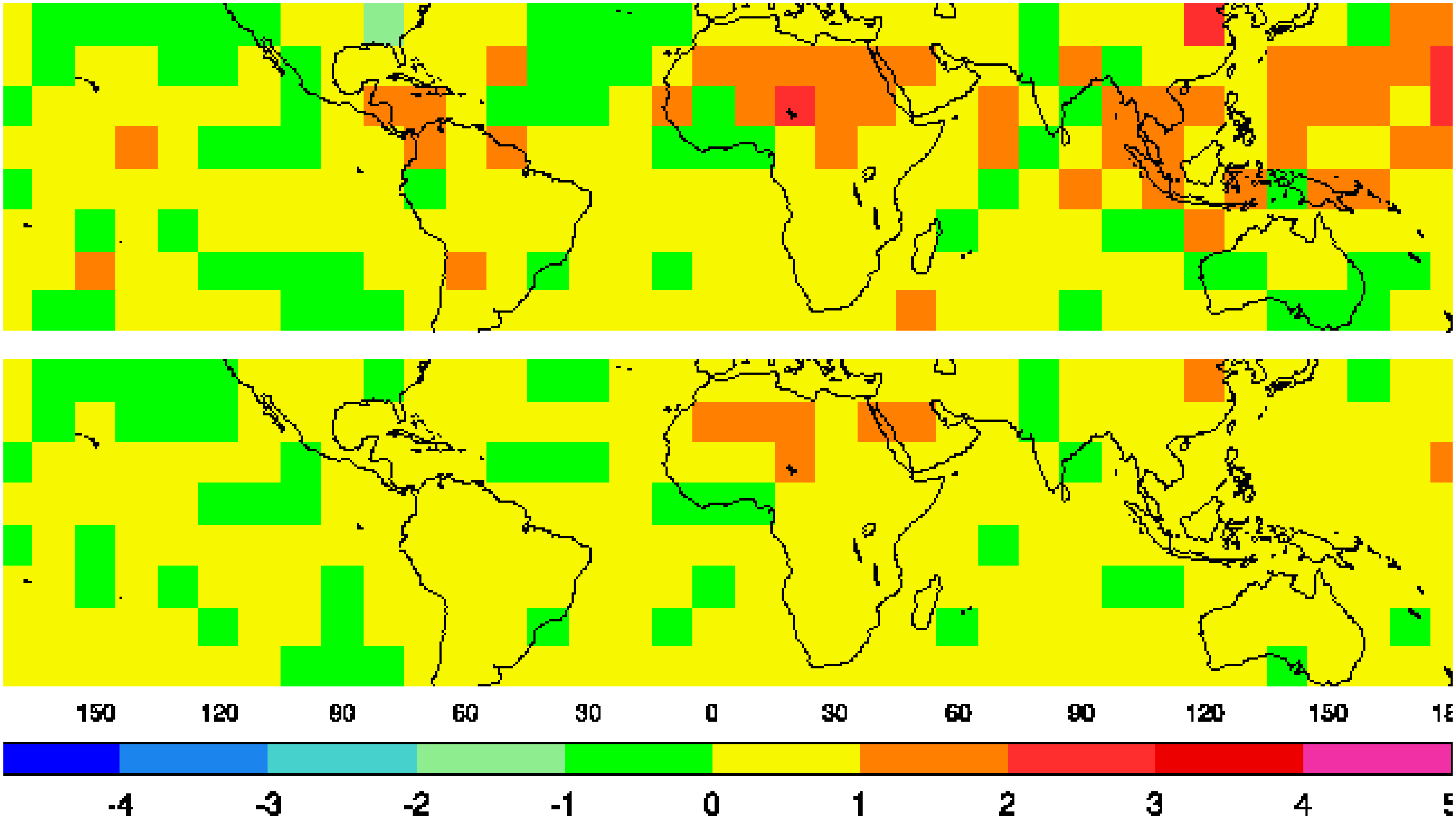
VALIDATION OF ADMS

- Assess accuracy of regional all-sky fluxes by comparing mean ADM-derived fluxes with fluxes inferred by direct integration of mean radiances.

- Data: RAPS/Alongtrack (Daytime only)
  June - August 1998

- Target Area: 10 x 10 deg

LW AND WINDOW FLUX COMPARISON (NEW ADM - DIRECT INTEGRATION)
FOR JUNE - AUGUST 1998



ΔL (W/m^{-2})

- RESULTS OF VALIDATION STUDY
  - Regional flux differences between the empirical ADM-derived fluxes and fluxes computed by direct integration method are typically less than +/- 1.0 W/m^{-2} for both longwave and window channels.

SUMMARY

- New CERES LW and WN angular distribution models have been developed using coincident VIRS imager and CERES measurements on TRMM.

- These models are stratified by cloud and clear sky parameters that influence the LW and WN anisotropy of earth scenes.

- Preliminary validation results indicate that LW fluxes from the new ADMs show a factor of 2 reduction in error compared to ERBE.